MASS. UM402.2:SU17

UMASS/AMHERST
312066 0269 6035 2

THE MASSACHUSETTS
TOXICS USE REDUCTION INSTITUTE

GOVERNMENT DOCUMENTS
COLLECTION
OCT 2 7 1999
University of Massachusetts
Depository Copy

SUBSTITUTION CASE STUDY:

ALTERNATIVES TO SOLVENT AND PETROLEUM-BASED INKS

Technical Report No. 5 1993

University of Massachusetts Lowell

SUBSTITUTION CASE STUDY:

ALTERNATIVES TO SOLVENT AND PETROLEUM-BASED INKS

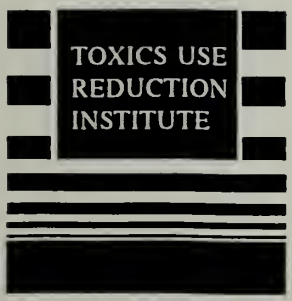
Prepared by:

Tellus Institute

Prepared for:

The Toxics Use Reduction Institute
University of Massachusetts Lowell

May 1993



All rights to this report belong to the Toxics Use Reduction Institute. The material may be duplicated with permission by contacting the Institute.

The Toxics Use Reduction Institute is a multi-disciplinary research, education, and policy center established by the Massachusetts Toxics Use Reduction Act of 1989. The Institute sponsors and conducts research, organizes education and training programs, and provides technical support to governments to promote the reduction in the use of toxic chemicals or the generation of toxic chemical byproducts in industry and commerce. Further information can be obtained by writing the Toxics Use Reduction Institute, University of Massachusetts Lowell, One University Avenue, Lowell, Massachusetts 01854.

©Toxics Use Reduction Institute, University of Massachusetts Lowell

printed on recycled paper

PREFACE

As more companies search for and develop environmentally safer production processes the need for information on cleaner production processes is on the rise. To promote knowledge of the availability of technically and economically feasible alternatives to toxic chemicals and products in the workplace, the Toxics Use Reduction Institute sponsors "substitution" studies. A substitution study focuses on input substitutes or process changes that eliminate or reduce the use of a toxic chemical or product and replace it with safer alternatives. The need for substitution studies arise because input substitution in manufacturing is a complex process. Factors that make input substitution a complex process include changes to product quality, product profitability, environmental and human health, and roles of employees. All of these factors must be included in a substitution analysis to understand the effects of input substitution. The purpose of the substitution studies is to provide an understanding of safer chemistries, processes, and products that are on the market and the benefits and costs to a manufacturer of switching to one of these alternatives.

The substitution studies prepared for the Toxics Use Reduction Institute are designed to provide information to technical assistance programs, manufacturers, and government toxics use reduction and pollution prevention programs on technically and economically feasible safer alternatives to toxic inputs. This report was prepared by the Tellus Institute for the Toxics Use Reduction Institute. The opinions expressed in this report are those of the authors and not necessarily those of the Toxics Use Reduction Institute.

TABLE OF CONTENTS

1. Introduction 1

2. Printing Processes 1

3. Lithographic Inks 3
   3.1 Heatset inks 4
   3.2 Non-heatset inks 5
   3.3 Newsprint inks 6
   3.4 Form inks 7
   3.5 Radiation curing inks 7

4. Flexographic and Gravure Inks 7

5. Conclusions 8

Endnotes 12

1. Introduction

Printing inks are a diverse group of petroleum and solvent-based materials. Components of ink vary with ink color, the paper or other material (also known as substrate) which is to be printed, the type of printing process used, and other characteristics specific to the desired end product. For example, inks used for printing bumper stickers must resist fading and be weather-proof, inks used for consumer packaging must be bright, and generally, inks must dry so they are smudge and rub resistant.

Section 2 of this report presents the major commercial printing processes. The characteristics of the inks used for processes which dominate the Massachusetts commercial printing industry and less toxic or non-toxic alternatives to these inks are presented in Sections 3 and 4.

2. Printing Processes

The commercial printing industry may be categorized by the various types of printing processes. The five major processes in order of increasing national and state market share are: screen, letterpress, flexography, gravure, and lithography. Each process uses a different method to transfer the printed image onto the paper or substrate that is to be printed, as well as different equipment and type of inks. Product quality and cost are the major factors determining which process is used for a particular application.

Screen printing, also known as silk screening, is the most versatile printing process as it can print on many substrates including paper, wood, glass, fabric, plastic, and metal. A stencil on the screen protects the areas that are not to be printed so that when ink is applied to the screen, it will only pass through the non-protected areas which comprise the image. As screen printing is considered a more specialized form of printing and is not widely used (it accounts for approximately 7% of all U.S. commercial printing)[1], alternative inks used for this process are not included in this paper.

Letterpress is the oldest printing method. Printing is accomplished by using plates in which the image or printing areas are raised above the non-image areas. When ink is applied to the plate, the ink rollers only touch the raised areas. The inked image is then transferred directly onto the paper. While previously plates were made using cast iron type, today typesetting is done primarily using computers. Since changes to the plate can be easily made, letterpress is used for printing literature that requires constant updating such as price lists, timetables and directories. Letterpress has been used for printing newspapers and magazines although many publications are switching to lithography. Books and advertising brochures can also be printed with letterpress. Since letterpress printing does not have a large market share (approximately 11% in the U.S.)[2], alternative inks used for this process are not included in this paper.

Flexography is a form of letterpress that uses flexible rubber plates that are mounted onto a rotating printing cylinder. Flexography is used to print a range of products including decorated toilet paper, corrugated board, foil materials, cellophane, polyethylene and other plastic films. Other uses include printing of milk cartons, business forms, books, folding cartons, and corrugated boxes. Because flexography can provide glossy brilliant colors, it is used for gift wrapping papers and shower curtains. In recent years, this process has been introduced to newspaper and magazine printing. Flexography accounts for approximately 17% of the U.S. commercial printing industry.[3]

Gravure is used for high quality publications and packaging. The plate has sunken areas that receives the ink and transfers it to the substrate. Due to the high cost of platemaking, gravure is typically used for high volume jobs. Rotogravure, which is used for printing on rolls of paper, is used for Sunday newspaper magazines, large run mail order catalogs, and postage stamps. Gravure printing represents 19% of the U.S. commercial printing market.[4]

Offset lithography accounts for approximately 46% of the commercial printing market nationally[5] and is the major type of commercial printing in Massachusetts.[6] Therefore the focus of this study is on ink substitutes available for this process.

There are two major differences between lithography and other forms of printing. First, the plate does not print directly onto the paper or other substrate being used. Instead, the plate transfers the ink to a rubber blanket and the blanket in turn transfers the ink to the substrate (hence, the name offset). The soft blanket surface provides a clearer impression than printing directly onto the paper or other substrate.

Second, the plate is flat; the part of the plate which provides the image is neither raised nor sunken. Instead, the plate works on the principal that oil and water do not mix. When the printing plate is made, the image section of the plate is rendered receptive to ink and non-receptive to water, while the converse is true for the non-image section - it is receptive to water and non-receptive to ink. The plate is wetted before receiving ink; the non-image portion of the plate retains the wetting solution, known as fountain solution. When the oil-based ink is applied, it will only adhere to that portion of the plate that did not retain the fountain solution. Therefore, an oil-based material is an important ingredient in offset inks.

Two types of presses are used for offset lithography - sheetfed or web. As the name implies, sheetfed presses print on single pieces of paper and are used for printing books, posters, labels, packaging, catalogs, greeting cards, folding boxes, coupons, and art reproduction. Web presses use large rolls, or webs, of paper and are used for printing business forms, newspapers, newspaper inserts, advertising literature, catalogs, books, and magazines. After the job is printed on the web it is can be cut to size, folded, and assembled. For large printing jobs, web presses are more economical to run than sheetfed presses. However, sheetfed presses can print on a greater diversity of paper types.

Web presses can be further classified based upon the presence or absence of a dryer. Heatset webs have a drying unit at the end of the web which dries, or sets the ink. Thus, the inks used by these webs are known as heatset-inks. Webs that do not have this drying unit use non-heatset inks that dry by absorption into the paper. This latter type of ink is also used by sheetfed presses.

3. Lithographic Inks

The components of ink include pigments which provide the color and consist of organic or inorganic materials, resin vehicles which act as carriers of the pigment, solvents or other fluids to dissolve the resins and control the body and viscosity of the ink, and other additives that impart other characteristics to the ink depending upon its application. Waxes, lubricants, and driers are some of the additives found in ink.

Vegetable oils were the original vehicles used in lithographic inks. As high-speed presses were introduced, vegetable oil-based inks fell out of favor because the inks required too much time to dry. Quicker drying petroleum oil inks eventually replaced the vegetable inks.

Today, petroleum oils are a component of all lithographic inks, serving as a vehicle for the pigment and providing body and viscosity to the ink. These oils are composed primarily of normal paraffins and naphthenic fractions of a petroleum distillate.[7] The presence of these oils may pose potential environmental and worker health and safety concerns if improperly used or stored. In the workplace, skin exposure to petroleum oil-based ink may cause skin irritation and inhalation may cause dizziness and drowsiness. The Occupational Safety and Health Administration (OSHA) has various housekeeping requirements which are designed to minimize exposure to employees. There are currently no specific OSHA permissible exposure levels (PEL)* for lithographic inks. However, the PELs for oil mists (5 mg/m^3), naphtha solvents (100 ppm), and petroleum distillates (400 ppm), and others have been used for comparative purposes.

Due to the volatility of petroleum oils, volatile organic compounds (VOCs), which are precursors to ground-level ozone formation, may be generated from the use of inks. Ozone causes lung, eye, and other mucous membrane irritation and can cause permanent lung damage. While the VOC content of printing inks is not regulated, emissions of VOCs are regulated by individual states and the U.S. EPA. In Massachusetts, a commercial printer is considered a major source of air emissions if greater than 50 tons/year of VOCs are emitted. The potential to emit is calculated based upon the maximum capacity of the equipment, assuming that the equipment runs 24 hours per day and 365 days per year or as limited by an enforceable operating permit through limitation of operating hours or production unit quotas. The amount of ink oil retained in the printed product and the amount of discarded solvents

*The PEL is a time-weighted average concentration for an 8-hour workday and 40-hour workweek, to which nearly all workers may be repeatedly exposed without causing an adverse health effect.

and inks are credited against the potential to emit figure.[8] If the facility has the potential to emit greater than 50 tons of VOC per year, it is required to implement control technologies to reduce air emissions to the environment. In addition, majors sources must maintain accurate production and emission inventory records. Because compliance with major source requirements represent a significant administrative burden and capital expense, most printers will try to operate at conditions below the 50 tons per year VOC threshold. Clearly, a direct method for staying below this trigger level is the use of low VOC containing raw materials.

In response to environmental concerns, ink manufacturers are re-examining the use of vegetable oils and have introduced inks with a lower VOC content, substituting the petroleum oil with either soy oil or vegetable oils such as tung or linseed. While these inks are commonly known as soy or vegetable inks, the name is a misnomer - all "vegetable" inks contain a certain amount of petroleum oil. As in the earlier days when soy- or vegetable-based inks were used, these inks dry much slower than petroleum-based inks. The extra time required for drying vegetable-based inks poses an unacceptable delay in production time. Therefore, a certain amount of petroleum oil is maintained in the ink to hasten drying. Thus, while vegetable inks reduce the health effects associated with VOCs, these effects may not be totally eliminated.

Substituting conventional inks with vegetable inks does not require any equipment changes. Thus, the main variable between these inks is composition. The ingredients in an ink, including the type of oils, depends upon the type of substrate being printed, the ink color, type of press and many other factors. To assist this comparison, the different categories of lithographic inks and the ink oils used in each category are discussed below.

3.1 Heatset inks

These inks are only used with heatset webs where the high temperature (200 - 300° F) of the dryer is required to set the ink. As the heat also causes volatilization of ink oils, heatset inks generate the most VOCs.

The VOC content of these inks can be as low as 30 to 35% by weight.[9] As the solvent is important for controlling the viscosity and tackiness of the ink, it can only be reduced to a certain point without adversely affecting product quality. In addition, further increasing the amount of soy or vegetable oil in the ink requires a higher operating temperature for the dryer; at the higher temperature, the paper will begin to scorch. Therefore, "soy" heatset inks commonly contain 35-40% petroleum oils by weight.

To receive the American Soy Association's (ASA) "Soy Seal," a heatset ink must contain 10% soy oil by volume (see Table 1). The ASA promotes the use of soy inks and has set minimum soy contents for various printing inks based upon the feasibility of use for each formulation. In the case of heatset inks, ASA has set the lowest soy content due to the difficulty of drying the ink in the dryer. The soy content for these inks was originally set at

18%, but the ink manufacturers could not produce an acceptable ink with this soy content.[10] Thus, although it is the dryer that causes the generation of VOCs, it is also what limits the soy content. Substituting 10% soy oil for petroleum oil can however help reduce VOC emissions - soy heatset inks can provide a 16.6% reduction in VOCs as compared to conventional heatset inks.[11] This reduction however is accompanied by a 5 to 8 percent increase in the cost for ink.[12]

TABLE 1. SOY CONTENT OF PRINTING INKS RECEIVING ASA SOY SEAL

INK TYPE	MINIMUM SOY CONTENT
HEATSET	10%
NON-HEATSET	20%
NEWSPRINT	55%
FORM	40%

3.2 Non-heatset inks

These inks are used both on sheet-fed presses and non-heatset webs. Because these presses do not have dryers, the inks instead dry both by absorption into the paper and by oxidation, absorption of oxygen from the air which causes the ink to harden. The VOCs in the ink oils are not volatilized as much as heatset inks due to the absence of a dryer. Approximately 5% of the VOC content will be released during printing operations; the remainder stays in the ink.[13]

The soy or vegetable content of these inks is dependent upon the type of paper being printed. Uncoated stock can have a higher content of these oils as the paper is more absorbent. The soy content of inks used on coated stock is limited because coated stock is less absorbent; instead, oxidation of the ink plays a more important role in drying. Color is another important factor dictating soy content. Black inks, which are slower drying, can only contain approximately 20% soy oil while some of the other colors can contain 25% soy. To display the Soy Seal, non-heatset inks must contain a minimum of 20% soy oil by volume.

Substituting the petroleum oil in non-heatset inks with either soy or other vegetable oil-based inks involve trade-offs. The positive attributes of soy and other vegetable inks include reduction of VOC emissions associated with printing operations. Because soy oil is clearer than petroleum or linseed oils, in some applications soy oils can actually provide a better print quality and brighter appearing colors.[14] Some users of soy ink report better ink pickup and transfer, resulting in shorter production start-up time and less waste. The

drawbacks to soy oil include its slower drying; linseed and tung oils dry quicker than soy while still maintaining some of the same beneficial properties as soy oil. Soy and other vegetable oil-based inks have also tended to cost more than petroleum-based inks. This price difference is expected to be minimized in the future.

To obtain further information on soy and other vegetable-based inks, we contacted two commercial printers in Massachusetts. W. E. Andrews produces calendars, posters, catalogs, books, and flyers printed on sheet-fed presses and heat-set webs. The company uses both solvent- and soy-based inks. The use of soy inks is primarily customer driven - those customers who request recycled paper also tend to request soy inks. W.E. Andrews has found that the soy inks do not dry as hard as solvent-based inks on certain paper stocks, causing the ink to rub off. The print quality provided by the soy is equal, and at times even better than conventional inks. Currently the cost of soy inks is higher than conventional inks, but the company is not passing this cost difference onto their clients.[15]

Bosworth Printing uses both letterpresses and sheet-fed presses. When the company completely switched to soy and vegetable inks approximately three years ago, they found that the colors were printing too brilliantly. This problem was rectified by reducing the amount of ink applied. With experience, this problem was overcome and the company reports "only positive effects associated with the inks."[16] Bosworth reports no cost differences between solvent-based inks and their substitutes.

3.3 Newsprint inks

Newsprint inks bearing the Soy Seal must contain a minimum of 55% soy oil by volume, the highest soy content of any printing ink. Newsprint ink can have a higher soy content because the paper is very absorbent and the ink dries solely by absorption. As a result, all of the petroleum oil in news ink can be substituted with soy or vegetable oil.[17]

Thus far, soy oil has mainly been used in color inks. For color inks, the majority of the cost is due to the pigment (the cost of a colored pigment is $3 - $4 per pound) while the ink oil represents a small percentage of the price.[18] Therefore, even though the soy oil costs more than the petroleum oil, this price differential is small in relation to the pigment price. One newspaper publisher, The Juneau Empire, has reported that even though colored soy-based inks cost more than conventional inks, pound for pound the soy inks print more copies therefore eliminating the cost differential.[19] For black inks, the pigment cost is insignificant (approximately 30 cents per pound) while the oil price dominates the total ink cost. Therefore, black soy-based inks are more expensive than black solvent-based ink. Soy-based newsprint inks can be as much as 30% more expensive than conventional newsprint inks.[20] However, some ink manufacturers are providing soy-based inks at prices comparable to solvent-based inks.[21] As the price difference diminishes, newspapers may increase their use of soy inks.

3.4 Form inks

Business forms are printed on non-heatset web presses. As with newsprint inks, form inks can contain a higher percentage of soy or vegetable oil since the paper used for printing business forms is absorbent. Inks using the Soy Seal must contain a minimum of 40% soy oil.

3.5 Radiation curing inks

Radiation curing inks are another alternative to oil-based lithographic inks. There are two types of radiation curing inks that contain no solvents: ultraviolet (UV) and electron beam (EB) inks. UV inks consist of one or more monomers and an initiator which, on exposure to UV radiation, release free radicals that polymerize or "cure." These inks can be used both on sheetfed and web presses. Because the ingredients in UV inks are expensive, they are approximately twice the cost of conventional solvent-based inks. Therefore, their use has mostly been limited to luxury packaging such as liquor and cosmetic boxes, metal decorating, and screen printing.[22] The main advantage to using UV inks is that they contain no solvents and therefore decrease worker exposure to solvents in the printing industry. Because these inks do not set until exposed to UV light, the ink does not dry up on the press, reducing press cleaning time. However, the reaction of UV light with oxygen forms ozone and the UV lamp must be properly shielded to prevent employee exposures. The UV unit also poses an additional capital expenditure.

EB inks are similar to UV inks, but are not as expensive. As with UV inks, their use decreases worker exposure to solvents since these inks are formulated without solvents. However, x-rays are created by the use of EB inks so proper operation protection is needed. The major disadvantage to EB inks is the high capital cost of equipment.[23]

4. Flexographic and Gravure Inks

These two inks are discussed together as their chemical and operational properties are similar. Gravure inks are rapid drying inks which must have the proper viscosity in order to be pulled down from the sunken area of the plate containing the ink. Flexographic inks are also quick drying and have a viscosity similar to that of the gravure inks.

Conventional flexographic and gravure inks commonly contain alcohols such as ethyl alcohol and isopropyl alcohol. These alcohols are flammable and pose worker health and safety risks including irritation to the eyes and upper respiratory tract, headaches, drowsiness, and dizziness. The OSHA PEL for both alcohols is 1000 parts per million (ppm).[24,25]

Most printers using flexography and gravure have substituted water-based inks for the alcohol-based inks due to concerns with worker health and safety, flammability, and high

insurance costs. The substitution provides a cost savings in several areas. For example, Cleo Wrap in Memphis, Tennessee substituted water-based inks for solvent-based inks in its rotogravure production of wrapping paper. This substitution provided an annual waste disposal cost savings of $35,000 as the water-based ink eliminated land disposal of a hazardous material. Reduced fire insurance premiums provided another cost savings.[26]

The switch to water-based inks at Cleo Wrap was accompanied by plant modifications and increased ink costs. Due to the different characteristics of the water and solvent-based inks, the printing cylinders had to be replaced with ones that have shallower etchings. The replacement cost for seven print cylinders and installation of a steam cleaning tank for the new cylinders was $3,500 in 1978. The water-based inks were priced slightly higher than conventional gravure inks at the time of the substitution; this cost difference is expected to decrease. Finally, plant personnel had to be retrained to work with water-based inks.

MPI Label Systems in Illinois uses flexography for label printing. In 1988 the company began replacing alcohol-based inks with water-based inks and replacing solvent-based cleaners with a detergent cleaner. U.S. EPA recently completed a study at MPI comparing the volume and toxicity of waste associated with both types of inks.[27] While the study concluded that solid and liquid wastes generated from use of both inks is approximately the same, the liquid wastes from the water-based ink do not require disposal as hazardous wastes. Air emissions of solvents have been significantly reduced with the substitution, and the toxicity of the emissions is also reduced. The substitution of water-based ink for alcohol-based ink has provided a $16,500 annual cost savings for the firm due to the elimination of hazardous waste disposal and a reduced insurance rate. There were no significant cost differences between the two types of inks or cleaners.

As with Cleo Wrap, MPI experienced some operational changes with the substitution. The rubber printing plates that were used with the alcohol-based inks did not produce a satisfactory image with the water-based inks; these were replaced with plastic plates. More energy has been required to dry the labels. However, this has been offset by a 10% increase in press speed with the water-based inks. MPI also found that a better quality label was produced by the substitution.

The substitution performed by MPI is also applicable to the newspaper industry. As newspapers have purchased new presses in recent years, many have switched from lithography to flexography. This is due to the faster press speed, reduced disposal costs, and elimination of VOC-containing fountain solutions.[28]

5. Conclusions

Offset lithography is the major printing process used by commercial printers in Massachusetts. Solvent-based offset lithographic inks contain petroleum oil which is regulated in the workplace by OSHA. In addition to worker health and safety, these oils

present an environmental concern as well. Petroleum-based inks are volatile and cause VOC emissions, precursors to the formation of ground level ozone.

To reduce the VOC content of inks, manufacturers have substituted petroleum oil with vegetable oils such as soy, linseed and tung. The characteristics of these substitutes are summarized in Table 2. The degree to which these oils can replace petroleum oils depends upon the type of press used for a specific job, the type of paper being printed, and the color of the ink. Soy and other vegetable inks dry slower than conventional inks, especially if the paper is not very absorbent. Therefore, more absorbent paper, such as newspaper and business forms, can use inks with greater vegetable oil content whereas coated stock, which is not very absorbent, cannot use an ink with a high soy or other vegetable oil content. Heatset inks can tolerate the lowest amount of soy oil as the dryer temperature required to dry such an ink would scorch the paper.

Several positive effects have been attributed to the use of soy oil. Soy oil is lighter in color than petroleum oil; as a result, colors appear brighter. Other advantages include greater stability, less tendency to develop a skin if the ink sits around for awhile, less susceptibility to piling (ink build-up on the printing plate), and better color control.[29]

Another advantage to using soy or other vegetable ink is the resulting reduction in VOC content of the ink. However, the inks that generate the most VOCs upon use, heatset inks, can tolerate the smallest soy or vegetable oil content. The VOCs contained in other offset inks are mostly absorbed into the paper; little is released into the environment.

Several experts in the printing industry also noted that printing inks are not the major source of solvents or VOCs in the industry: fountain solutions contain glycol ethers, solvents are used to clean the presses and blankets, and coatings may be solvent-based. These sources represent far greater uses of solvents and generation of VOC emissions.

In sum, trade-offs exist in using soy or vegetable inks versus conventional petroleum oil-based inks. Soy and other vegetable-based inks provide several beneficial printing properties but dry slower than petroleum-based inks. Certain types of lithographic inks are more expensive if the petroleum oil is substituted with soy oil. However, it appears that these price differences are diminishing.

UV and electron beam inks are another alternative to conventional inks. These inks contain no solvents, thereby eliminating VOC emissions and worker exposure to ink solvents. However, the cost of these inks are higher and capital expenditures for new equipment is required.

Gravure and flexographic inks contain alcohol-based solvents. Due to environmental concerns and insurance costs associated with use of these inks, the solvents have largely been replaced with water. Benefits of this substitution include elimination of hazardous waste disposal associated with inks, reduced insurance costs, and better print quality.

TABLE 2. SUMMARY OF ALTERNATIVES TO PETROLEUM- AND SOLVENT-BASED LITHOGRAPHIC, FLEXOGRAPHIC, AND GRAVURE INKS

Alternative Ink Product	Ink Attributes	Technical Advantages	Technical Disadvantages	Capital Costs	Operating Costs	Product Quality	Environmental and Occupational Health
Lithographic Soy-Based Heat-Set Web Press Inks Inks include 10% soy oil content by volume and 35-40% petroleum oil by weight.	Inks must withstand high drying temperatures (200-300° F), dry quickly, & have the proper viscosity & tackiness.		Slower drying time.	No capital costs.	Soy-based inks are 5-8% more expensive than conventional inks.	Similar quality.	Lower VOC emissions and worker exposure to petroleum oils.
Lithographic Soy-Based Non-Heat Set Inks Inks include 20-25% soy oil content by volume.	Inks must dry by absorption and oxidation, dry quickly, and produce bright clear colors.	In some applications, better print quality, brighter appearing colors, better ink pick-up, and transfer.	Slower drying time.	No capital costs.	Soy-based inks are slightly more expensive than conventional inks.	Similar quality, with brighter colors and improved clarity.	Lower VOC emissions and worker exposure to petroleum oils.
Lithographic Soy-Based Newsprint Inks Inks include 55% soy oil content by volume. Oil-based newsprint inks can be completely replaced by soy or vegetable oils.	Inks must dry solely by absorption.	Produce high quality color printing.	Slower drying times.	No capital costs.	Soy-based color inks are slightly more expensive, but can produce more copies/pound of ink, minimizing cost differential. Soy-based black inks cost 0-30% more than conventional inks.	Higher quality color printing and similar quality black inks.	Lower VOC emissions and worker exposure to petroleum oils.
Lithographic Form Inks Inks include 40% soy oil content by volume.	Form inks are used in non-heatset web presses and must dry solely by absorption.		Slower drying time.	No capital costs.		Similar quality.	Lower VOC emissions and worker exposure to petroleum oils.
Lithographic Ultraviolet Radiation (UV) Curing Inks For use in sheet-fed and web presses.	UV inks consist of one or more monomers and an initiator that are cured by UV light.	Press cleaning time is reduced because no solvents are used.		High capital costs to purchase UV equipment.	UV inks are twice as expensive as conventional inks.	Print quality is not as clear.	VOC emissions and exposure to petroleum oils are eliminated. Workers must be protected from ozone emissions and exposures to the UV lamp. Greater energy use. UV inks make recycling of the paper more difficult.

TABLE 2. SUMMARY OF ALTERNATIVES TO PETROLEUM AND SOLVENT BASED LITHOGRAPHIC, FLEXOGRAPHIC, AND GRAVURE INKS (continued)

Alternative Ink Product	Ink Attributes	Technical Advantages	Technical Disadvantages	Capital Costs	Operating Costs	Product Quality	Environmental and Occupational Health
Lithographic Electron Beam (EB) Radiation Curing Inks For use in sheet-fed and web presses.	EB inks consist of one or more monomers and an initiator that are cured by an electron beam.	Press cleaning time is reduced because no solvents are used.		High capital costs to purchase EB equipment.	EB inks are more expensive than conventional inks.	Print quality is not as clear.	VOC emissions and exposure to petroleum oils are eliminated. Workers must be protected from exposure to x-rays. Greater energy use. EB inks make recycling of the paper more difficult.
Flexographic and Gravure Water-Based Inks	Flexographic and gravure inks must be rapid drying and have the proper viscosity.	Presses can run faster in some cases.	Un-satisfactory images may be produced, requiring new capital equipment.	Low to moderate to purchase printing cylinders and plates.	Lower due to faster press speed, reduced hazardous waste disposal costs, and reduced insurance costs.	Similar product quality with new capital equipment.	Eliminate the use of alcohol- and other solvent-based inks reducing VOC emissions and worker exposures. Greater energy use for drying.

Endnotes

1. Bruno, M., ed. *Pocket Pal - A Graphic Arts Production Handbook*, International Paper, 1989.

2. *ibid.*

3. *ibid.*

4. *ibid.*

5. *ibid.*

6. Personal communication with Stig Bolgen, Printing Industries of New England, August 1992.

7. Jones, G.A. "Nonheatset lithographic VOC emissions and their reduction," *GATFWORLD* 2(3): 34, 1990.

8. Jones, G.A. "Impact of air pollution regulations on printers," *GATFWORLD* 2(4): 29, 1990.

9. National Air Pollution Control Techniques Advisory Committee, *Draft Control Technique Guideline for Offset Lithographic Printing*, Sept. 1991.

10. Personal communication with Stu Ellis, American Soybean Association, Sept. 1992.

11. Blessing, R. "Soy Ink? So What?," *Publishing & Production Executive*, Jan/Feb 1992, p. 44.

12. *ibid.*

13. Personal communication with Gary Jones, Graphic Arts Technical Foundation, Aug. 1992.

14. "Soy Ink - Just Full of Beans?" *Printing Manager*, July/Aug. 1991.

15. Personal communication with Ed Holland, W.E. Andrews, Aug. 1992.

16. Personal communication with Gerald Judge, Bosworth Printing, Sept. 1992.

17. Personal communication with Paul Wolpe, National Association of Printing Ink Manufacturers, Sept. 1992.

18. "Soy Ink - Just Full of Beans?," *op. cit.*

19. Personal communication with Tom Blumenshine, The Juneau Empire, January 1993.

20. "Soy Ink and the Environment," fact sheet produced by Superior Ink Company, July 8, 1991.

21. "Soy Ink - Just Full of Beans," *op. cit.*

22. Bruno, M., ed., *op. cit.*

23. *ibid.*

24. American Conference of Governmental and Industrial Hygienists, *Documentation of the TLVs and Biological Exposure Indices*, 5th ed, 1986.

25. *NIOSH Pocket Guide to Chemical Hazards*, 1985.

26. Institute for Local Self-Reliance, *Proven Profits from Pollution Prevention - Case Studies in Resource Conservation and Waste Reduction*, Vol. II, 1989.

27. Randall, P.M., *et al.* "Toxic substance reduction for narrow-web flexographic printers," presented at 17th Annual EPA Hazardous Waste Research Symposium, Cincinnati, OH, April 1991.

28. Personal communication with Paul Wolpe, National Association of Printing Ink Manufacturers, Sept. 1992.

29. "A Realistic Appraisal of Soya Inks," National Association of Printing Ink Manufacturers, October 1991.